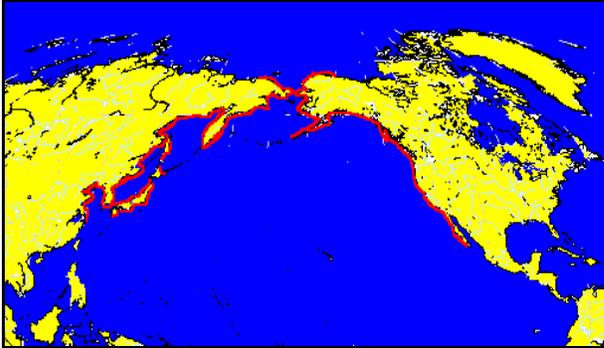


3.3.9 Pacific Herring *Clupea pallasii*



Distribution map for adult Pacific herring

Adult Range: From northern Baja California to Toyama Bay, Japan, westward to the Yellow Sea.

Life History: Size: Up to 46 cm (18 in.) and 550 g (1.2 lb); Age at maturity: two to three years old; Fecundity: 4,000 to 130,000 eggs; Life Span: Alaska- to nineteen years, California- to eleven years.

Adult Habitat: A schooling species found near shore to hundreds of miles off shore; spawns in intertidal and sub-tidal zones.

Adult Fishery: Commercial: valuable roe fishery; Recreational: small pier and shore angler fishery.

Pacific herring belong to the order Clupeiformes, which contains some of the world's most numerous and economically important fishes (e.g., herring, sardine, anchovy). The distribution of the Pacific herring extends from Baja California to the north Pacific and westward to Japan and the Yellow Sea (Miller and Lea 1972). In North America, Pacific herring range from Baja California north to arctic Alaska (PSMFC 1999a) and are most abundant off Alaska and British Columbia. In California, most of the populations are found in the San Francisco and Tomales bay areas (Fitch and Lavenberg 1975). Pacific herring are found from nearshore areas to hundreds of miles off the coast (Love 1996). They were collected in all Morro Bay fish studies (Appendix B this document, Fierstine et al. 1973, Horn 1980, Behrens and Sommerville, CDFG unpubl. otter trawl data, 1999–2000 impingement study [Section 4.0]).

Pacific herring are small, streamlined marine fishes, measuring up to 46 cm (18 in.) in length and weighing up to 550 g (1.2 lb) (PSMFC 1999a). While Pacific herring stocks living in the waters off of Alaska and Canada tend to grow larger and live longer, in California they may live to eleven years of age and rarely exceed 30.5 cm (12 in.) in length (Fitch and Lavenberg 1975). California Pacific herring reach maturity at two to three years of age and at a length of 16.5 to 17.8 cm (6.5 to 7 in.) (Love 1996).

The spawning activity of Pacific herring is largely influenced by their geographical location. In California, spawning is known to occur in San Diego Bay, San Luis River, Morro Bay, Elkhorn Slough, San Francisco Bay, Tomales Bay, Bodega Bay, Russian River, Noyo River, Shelter Cove, Humboldt Bay, and Crescent City Harbor (Leet et al. 1992). Fish begin entering protected coastal bays, estuaries, and shallow nearshore environments approximately two months prior to spawning (Eldridge 1977). In the Moss Landing and Elkhorn Slough area spawning has been observed from November through July (Hardwick 1973).

The majority of spawning habitat is near vegetation in shallow waters ranging from the mean low-tide level to a depth of approximately 4 m (13 ft). The substrate of the spawning grounds tends to be clean, hard, and covered with gravel. Other substrate may include rocks, pilings, and jetties. A soft, muddy bottom may be used if a vegetative cover is available. Males and females spawn simultaneously over a period of one to seven days (Miller and Schmidtke 1956). The fertilized eggs, broadcast mostly at night, are adhesive and commonly attach to eelgrass, algae, and other intertidal vegetation (Hardwick 1973). Thousands of females repeatedly deposit their eggs on the vegetation, which can result in egg masses from 10 to 15 layers thick (about 5 cm [2 in.]) (Love 1996). In large spawning runs, a 9-m (30-foot) wide band of herring eggs may span a distance of 20 miles along the shoreline (Leet et al. 1992). In Elkhorn Slough, Pacific herring are known to broadcast eggs on pickleweed *Salicornia* spp., a brackish marsh vegetation (Wang 1986). Females are capable of spawning only once per season, and after producing between 4,000 and 130,000 eggs, they promptly return to the ocean, leaving the eggs to incubate and hatch. The rate of egg development varies with surrounding water temperature; Pacific herring eggs commonly hatch within 10 to 14 days at 11.8° to 13.5° C (53.2° to 56.3° F) (Wang 1986).

Hatch length is reported as 5.6 to 7.5 mm (0.2 to 0.3 in.) (Moser 1996). Shortly after hatching, and as the eyes become pigmented, the threadlike larvae move toward the surface waters. They tend to concentrate near the surface and remain for a long time in the area of the spawning grounds. Some larvae, however, have been found several miles out to sea, drifting with the currents (Fitch and Lavenberg 1975). It takes about 70 days (when larvae are approximately 26 mm TL [1.0 in.]) for the larvae to metamorphose (Hay 1985). Metamorphosis is complete by 35 mm TL (1.4 in.) (Stevenson 1962). Juveniles, depending on geographical region, range from 35 to 150 mm TL (1.4 to 5.9 in.) (Reilly 1988).

Herring usually reach maturity in two to three years in California and three to four years in Washington (Hart 1973). Pacific herring are pelagic, and while some may remain in

the bays and estuaries, most leave and return to the ocean (Eldridge 1977). At all life stages Pacific herring are plankton feeders, primarily selecting copepods, amphipods, fish larvae, and mollusks. They do not feed during the spawning season, but feed intensively in the summer after spawning.

Pacific herring are a well-described species with both age- and stage-specific mortality estimates available from the scientific literature. Egg mortality has been estimated to range from 20 percent (Hourston and Haegele 1980) to as high as 99 percent (Hardwick 1973, Leet et al. 1992). Larval mortality can also be derived from the literature and is assumed to be 99 percent through settlement (survivorship = 0.221). Data on larval age and growth (e.g., Stevenson 1962, Alderdice and Hourston 1985) are also important for estimating survivorship. Total adult mortality has been estimated as about 50 percent annually ($z = 0.69$) by Hourston and Haegele (1980). Estimates of natural adult mortality (m) are in close agreement from a variety of studies: $m = 0.4$ to 0.5 (Trumble and Humphreys 1985), $m = 0.39$ (Fried and Wespestad 1985), $m = 0.36$ (Schweigert and Hourston 1980), $m = 0.56$ (Gunderson and Dygert 1988), and $m = 0.31$ to 0.71 (Stocker et al. 1985).

The harvest of Pacific herring is a multi-million dollar industry in the United States, with most of the fish coming from Alaska, Washington, and California. The Pacific herring fishing industry is highly regulated north of San Francisco Bay. There are small fisheries in the Monterey and San Francisco area that target Pacific herring for bait and food, but the more valuable fishery involves herring eggs (roe). There is a very lucrative export market for herring roe, especially for kazunoko kombu (roe-on-kelp) which is considered a delicacy in Japan. There are a limited number of gill net and roe-on-kelp permits issued for this fishery in San Francisco Bay. Large amounts of giant kelp, transported from the Channel Islands, are suspended from rafts, which are then anchored in the Pacific herring spawning grounds. At the end of the spawning period, the kelp and attached eggs are collected, packed in salt, and exported to Japan.

3.3.9.1 Pacific Herring Results

Peak larval concentration for Pacific herring collected at the MBPP intake station occurred in December of both 1999 and 2000 (Figure 3-40), which agrees with reported spawning periods from November through July (Hardwick 1973). Larval concentrations were significantly higher in December 2000 than in December 1999. Pacific herring larvae continued to be collected through April but in much lower concentrations. A representative sample of Pacific herring larvae had a size range of 4.2 to 9.1 mm (0.17 to 0.36 in.), with an average size of 7.1 mm (0.28 in.) (Figure 3-41). These larvae are newly

hatched and only a few days old, based on the estimated hatch length of 5.6 to 7.5 mm (0.2 to 0.3 in.) (Moser 1996).

Pacific herring utilize Morro Bay for spawning and therefore the highest concentrations of larvae occurred at stations 3 and 4 inside the bay (Figure 3-42). No Pacific herring larvae were collected at the Estero Bay station (Station 5), but they were found at Station 1 at the harbor entrance. Although the larvae were most common at the back bay stations their concentrations were not large enough to allow for a comparison between ebb and flood tides (Figure 3-43).

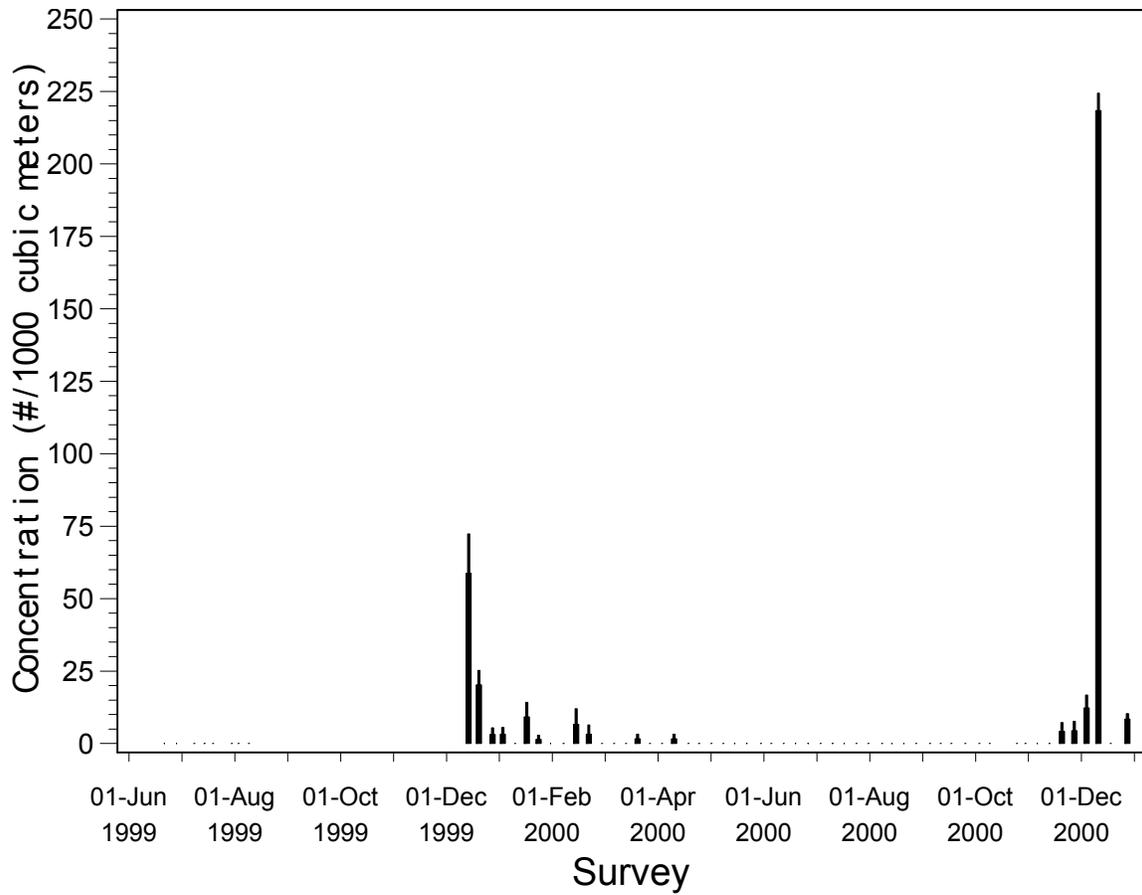


Figure 3-40. Weekly survey mean concentrations of larval Pacific herring collected at the MBPP intake station with standard error indicated (+1 SE). Weekly surveys were collected from June 21 through August 10, 1999 and from December 14, 1999 through December 29, 2000.

Note: The October 16, 2000 survey was cancelled due to the unavailability of a boat.

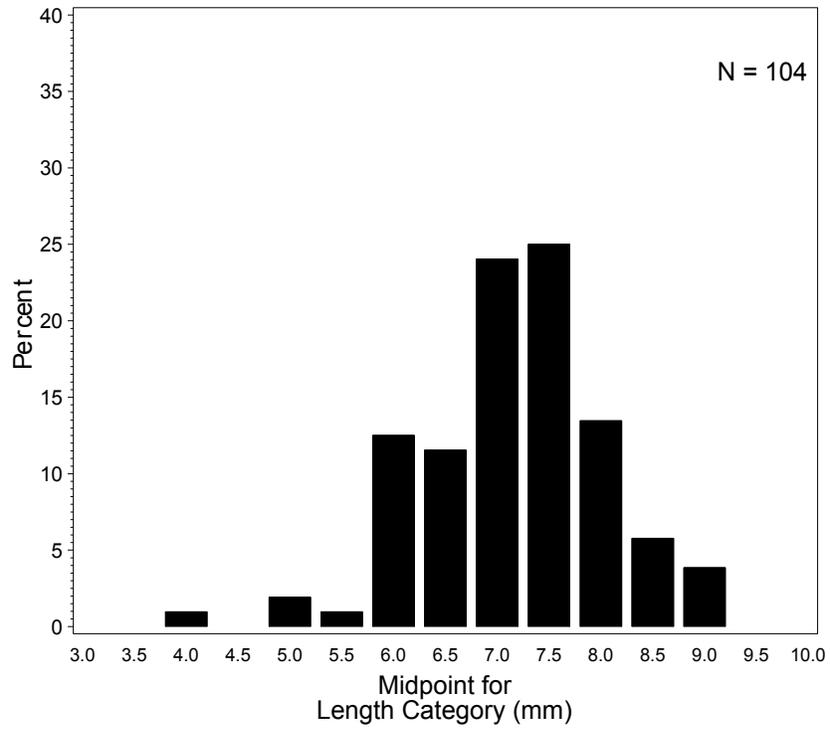


Figure 3-41. Length frequency distribution (mm) for Pacific herring larvae collected at the MBPP intake station from January – December 2000. The frequency distribution is based on the lengths of a representative sample of approximately 100 larvae.

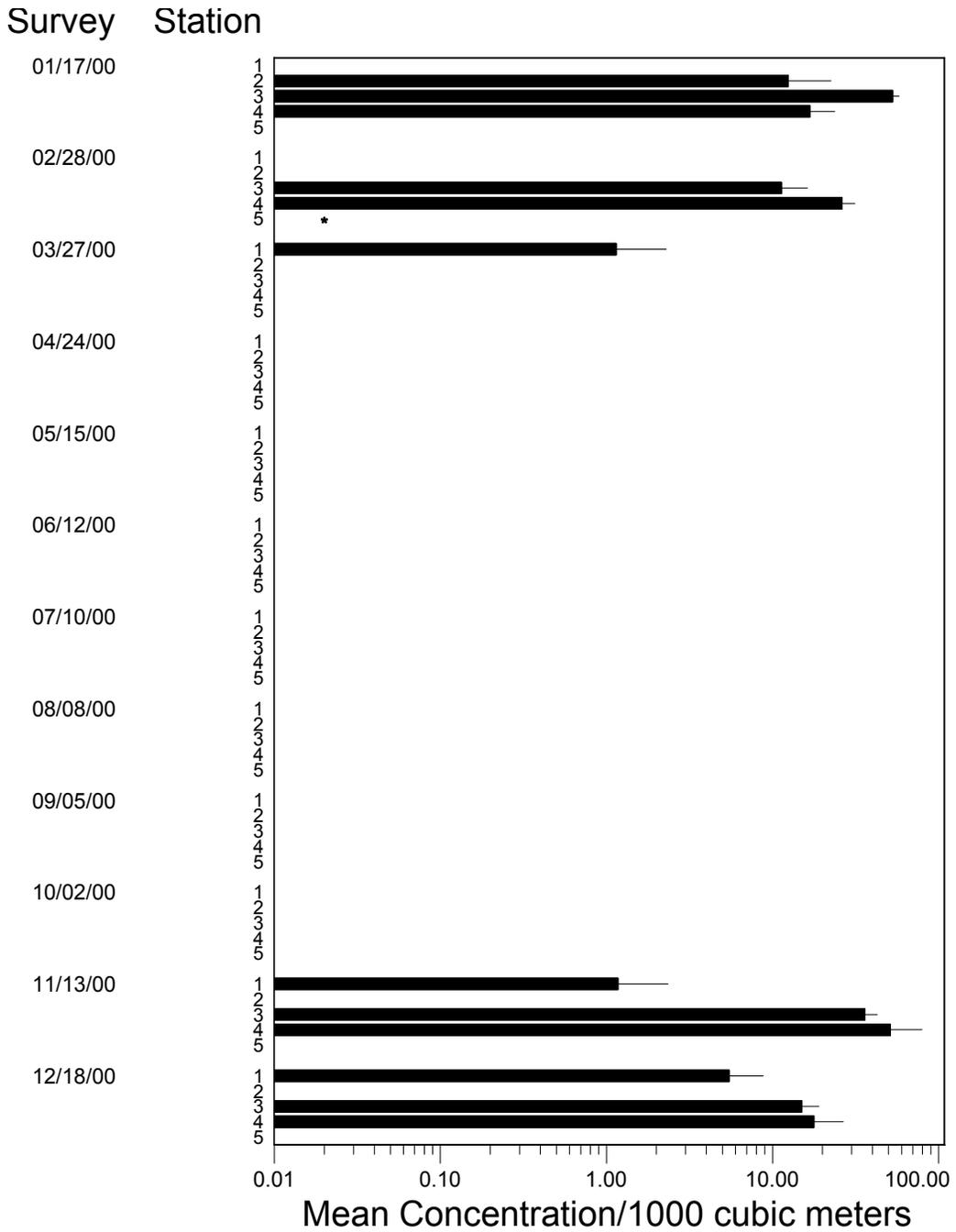


Figure 3-42. Mean larval Pacific herring concentration in monthly paired surveys at the MBPP intake (Station 2), Morro Bay source water (Stations 1, 3, 3, and 4), and Estero Bay (Station 5) from January – December 2000 with standard error indicated (+1 SE).

Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

* Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

Survey Station

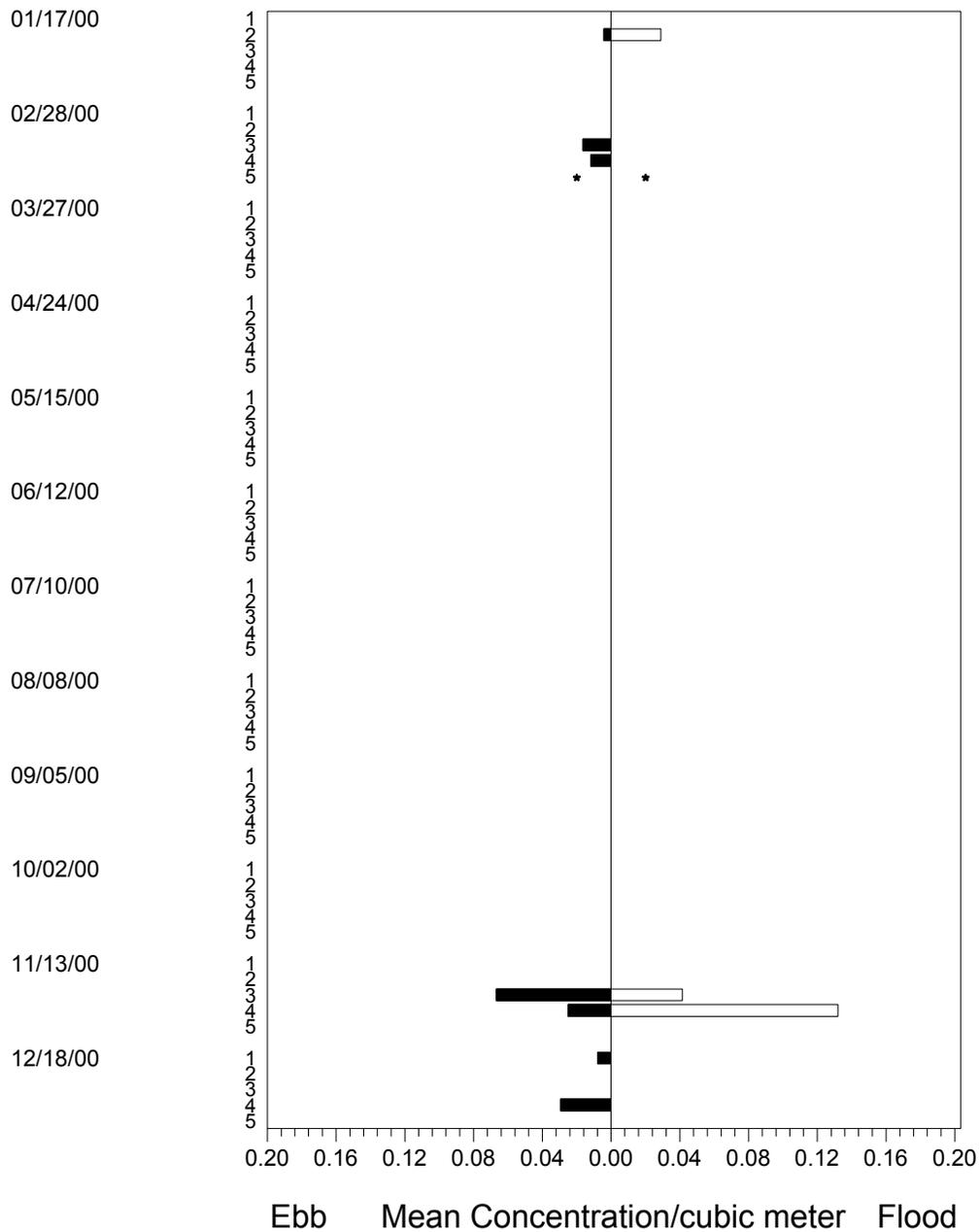


Figure 3-43. Mean concentration of larval Pacific herring from monthly paired surveys by tidal current (ebb – solid bars; flood – clear bars) and sampling station (Morro Bay stations 1–4 and Estero Bay Station 5) from January – December 2000.

Note: During the January 17, 2000 survey, source water stations 1, 3, 4, and 5 were sampled only in daylight hours. Beginning in February 2000 the sampling frequency was increased to cover a 24-hour period.

*Estero Bay Station 5 could not be sampled in February 2000 due to unsafe sea conditions.

